Preharvest and Harvest Food Safety

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Food Safety Hazards
• A
  – biological,
  – chemical, or
  – physical property
  that is reasonably likely to cause
  • cause injury or illness
  in the absence of its control

Chemical Hazards
• If not controlled will cause illness
  – Chemicals
    • Pesticides
    • Sanitizers
  – Allergens
    • Undeclared ingredients
    • Cross contaminants
  – Unapproved additives
  – Natural toxins
    • Mycotoxins
      – E.g., patulin

Physical Hazards
• Foreign objects capable of injuring the consumer
  – Metal
  – Glass
  – Wood
  – Hard plastic
  – Stones

Biological Hazards
• If not controlled will cause illness
  – Bacteria, e.g., Salmonella
    • Or their toxins
      (e.g., Clostridium botulinum toxin)
  – Viruses, e.g., hepatitis A
  – Parasites, e.g., protozoa
    • Cryptosporidium parvum

Produce Increasingly Recognized as Vector
• Proportion of reported outbreaks
  • USA
    – 1970s: <1% (outbreaks) <1% (cases)
    – 1990s: 6% (outbreaks) 12% (cases)
  • Australia
    – 4%: (2001-2005)
  • Europe
    – Increases in past decade

Lynch et al., Epidemiol. Infect. 2009
Multinational Outbreaks

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Cases</th>
<th>Regions</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Salmonella</td>
<td>1442</td>
<td>North America</td>
<td>Fresh peppers, tomatoes?</td>
</tr>
<tr>
<td>2007</td>
<td>Salmonella</td>
<td>51</td>
<td>Europe, North America</td>
<td>Fresh basil</td>
</tr>
<tr>
<td>2007</td>
<td>Shigella</td>
<td>175</td>
<td>Australia, Europe</td>
<td>Alfalfa sprouts</td>
</tr>
<tr>
<td>2007</td>
<td>Salmonella</td>
<td>45</td>
<td>Europe</td>
<td>Alfalfa sprouts</td>
</tr>
<tr>
<td>2006</td>
<td><em>E. coli</em> O157:H7</td>
<td>206</td>
<td>North America</td>
<td>Fresh spinach</td>
</tr>
<tr>
<td>2006</td>
<td>Salmonella</td>
<td>20+</td>
<td>Europe</td>
<td>Arugula</td>
</tr>
</tbody>
</table>

Lynch et al., Epidemiol. Infect. 2009

Why the increase?

- Increased consumption
  - More raw, less cooked
- Large scale production, widespread distribution
  - Increasing size of outbreak increases ability to detect
- Increase in sensitive populations
- Increase in public and scientific awareness
- Greatly improved methodology

1998 – 2006 Produce Outbreaks

Top 5 produce items make up 76% of outbreaks

- Lettuce/leafy greens: 24%
- Tomatoes: 30%
- Cantaloupe: 13%
- Herbs: 17%
- Green onion: 11%
- Other: 5%

Recurring Pathogen and Commodity Combinations

- *Salmonella* Poona and *Salmonella* Anatum
  - cantaloupes
- *E. coli* O157:H7 (other EHECs?)
  - lettuce and leafy greens
- *Salmonella*
  - mangoes, tomatoes, almonds (nuts)
- Hepatitis A
  - green onions
- *Shigella sonnei*
  - parsley, cilantro, and culantro

Do Fresh Cut Products Have Higher Risks?

1998-2006 Fresh Cut Produce Outbreaks

- Romaine lettuce: 2
- Lettuce: 6
- Mixed lettuce: 1
- Spinach: 2
- Roma Tomatoes: 2
- Round Tomatoes: 1
- Mixed melons: 1
Recent Outbreaks Have Caused Major Changes in Attitudes and Approaches to the Safety of All Perishable Produce

In the U.S., since 1999, 80% of leafy green outbreaks and 98% of illnesses have been from fresh-cut products.

Survival/Growth of Pathogens in Produce

- Intact fruit/vegetable
  - Survival variable, growth rare
- Cut/wounded fruit/vegetable
  - Survival increases and growth possible
- Temperature
  - Growth slowed at lower temperatures
  - SURVIVAL often increases at lower temperatures
- Humidity
  - Growth and survival enhanced with higher humidity

Growth of Pathogens in (cut) Produce

- High pH/low acid products:
  - Growth can be rapid at room temperature
  - examples: sprouts, cut melons, chopped parsley, chopped lettuce, shredded carrots
- Low pH/high acid products
  - Tomatoes: Under some conditions, chopped tomatoes will support the growth of Salmonella
  - Apples: Wound will support the growth of E. coli O157:H7

Innovative Packaging

- Longer shelf life due to suppression of spoilage organisms and physiological degradation
  - Modified atmosphere packaging
  - Vacuum packaging
  - Shrink-wrap packaging
  - Customized films
  - Controlled atmosphere storage

Toxin Production by Clostridium botulinum

<table>
<thead>
<tr>
<th>Product</th>
<th>Temp.</th>
<th>Days to Toxin</th>
<th>Product Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romaine</td>
<td>21</td>
<td>14 to 21</td>
<td>Inedible</td>
</tr>
<tr>
<td>Shredded cabbage</td>
<td>21</td>
<td>7</td>
<td>Inedible</td>
</tr>
<tr>
<td></td>
<td>22 to 25</td>
<td>4 to 6</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Sliced potatoes</td>
<td>22</td>
<td>3</td>
<td>Marginal</td>
</tr>
<tr>
<td>Sulfitated potatoes</td>
<td>22</td>
<td>4</td>
<td>Acceptable</td>
</tr>
</tbody>
</table>

Contamination/Handling Errors

- Have occurred at:
  - Production
  - Packing
  - Processing
  - Final preparation
- Contamination MOST important factor
- Temperature abuse SOMETIMES contributes
  - Most critical in low-acid fruits and vegetables
  - Pathogens can multiply when fruit or vegetable cut
  - Only critical with bacteria
Washing Doesn’t Eliminate Pathogens

- At best 1-3 log (1 to 1000-fold) reductions can be expected under commercial conditions regardless of antimicrobial used

- Issues
  - Complexity
  - Stem scar area
  - Apples
    - Bacteria can enter core through blossom end
    - Stem end difficult access
  - Presume knife can transfer to edible flesh
    - Demonstrated for melons and tomatoes

Infiltration Can Occur in Some Products

- Fruit pulp must be < 9°F warmer than water temperature to prevent infiltration.

Not all surfaces equal

- Smooth surfaces
  - Honeydew melon, tomato, oranges, apples

- Complex surfaces - hard
  - Netted rind difficult to “clean”
  - Scrubbing with clean brush significant improvement

- Complex surfaces - soft
  - Strawberries, broccoli, lettuce, parsley, sprouts

Some surfaces may attract bacteria

- Lettuce
  - *E. coli* O157:H7 found in cut edges and stomata (Seo and Frank, 1999)
  - *L. monocytogenes* and *Salmonella* attach to cut edges (Takeuchi et al., 2000)

Guiding Principles of Food Safety for Fresh Produce

- Once contaminated, removing or killing pathogens is VERY difficult

  THEREFORE

- Prevention of contamination is favored

GAPs and GHPs ARE Science-based

- Guidance derived from sound principles
- Data is lacking in many areas
- Specific practices and standards may
  - have no *validated* basis
Good Agricultural Practices
Now Incorporate More Specific “Metrics”:
Criteria for Compliance Audits

- Quantifiable and verifiable criteria
- Improve public safety by applying uniform science-based standards

Leafy Green Marketing Agreement
- Accepted More Specific and Prescriptive “Metrics”
- Voluntary Program; Mandatory Government Audits

FDA Produce Safety Rule
- The Food and Drug Administration is proposing to promulgate regulations setting enforceable standards for fresh produce safety at the farm and packing house.
- Intention to publish a proposed rule in 2011

What are the sources of contamination?

Enteric (Fecal) Pathogens (partial list)

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Enteric Source</th>
<th>Infectious Dose</th>
<th>Sequela</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>human</td>
<td>10 - 1,000</td>
<td>Reactive arthritis</td>
</tr>
<tr>
<td>Salmonella</td>
<td>human</td>
<td>10 - 1,000</td>
<td>HUS</td>
</tr>
<tr>
<td>E. coli O157:H7 (EHEC)</td>
<td>human</td>
<td>10 - 100</td>
<td>Dysentery</td>
</tr>
<tr>
<td>Shigella</td>
<td>human</td>
<td>10 - 100</td>
<td>Dysentery</td>
</tr>
<tr>
<td>Protozoa</td>
<td>human</td>
<td>&lt;20</td>
<td>Severe diarrhea</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>human</td>
<td>10 - 100</td>
<td>Jaundice</td>
</tr>
</tbody>
</table>

Routes of Contamination

- Plants
- Silage, feed
- Meat, milk, eggs
- Soil (cross contamination)
- Water
- Animals, birds
- Produce
- Humans
GAPs Metrics

- Mandatory Good Agricultural Practices (GAPs) developed by a panel of industry members, academics and scientists
  - Represent the best practices available
  - Flexible enough to evolve over time as science advances
  - Target water and inputs, wildlife and worker hygiene

Metrics

- Adjacent land use
- Distance from animal operations
- Water and water testing
- Application/testing of compost
- Sanitary facilities and worker training

Implementing GAPs

Step 1: Construct a Self-Audit of Potential Hazards

- Site selection
- Animal influences
- Fertility inputs
- Water inputs
- Irrigation
- Foliar sprays
- Harvest
- Human influences
- Worker hygiene
- Postharvest water and handling
- Sanitation – field and equipment

Best Practices: Site Selection

How far from an identified hazard?

Best Practices: Irrigation Water

Water Source

- Known
- Impaired
- Purified

How do you define water quality?

- Indicator threshold
- Pathogen testing
- Treatment

Best Practices: Irrigation Water

Water Source

- Oso Ranch 1 Block 2
- Baby Spinach Land Prep
- Pest Control
- Irrigation
- Packing

What factors should influence acceptability?

- Method of irrigation
- Type of crop
- Contact with edible portion
- Crop habit and surface morphology
- Cropping cycle
- Climate and microclimate
- Timing of last irrigation to harvest
Best Practices: Site Selection

What factors should influence acceptability?

- Slope
- Soil porosity
- Prevailing wind
- Presence of vectors
- Method of irrigation
- Crop habit + morphology
- Season
- Mitigation practices

E. coli O157:H7 Outbreak Associated with Bagged Lettuce (Taco Johns) (December 2006)

- 81 cases of E. coli O157 infection in three states
  - 2 cases of HUS, 26 hospitalizations
- Implicated vehicle – Bagged, fresh-cut lettuce
  - Grown in California’s Central Valley
  - Outbreak E. coli O157:H7 strain isolated from 2 environmental samples from 2 dairy farms near lettuce-growing area
- Irrigation water cross-linked to dairy waste water used to irrigate animal food crops
  - the farm irrigation system that utilized dairy runoff water did not have any backflow prevention devices to ensure manure-blended irrigation water did not contaminate the SWSD water system,” which was used to irrigate lettuce fields

E. coli O157:H7 Outbreak 2006
Bagged Fresh Spinach

- 45 of 351 (13%) of environmental samples in and around the Ranch were E. coli O157:H7-positive
  - Outbreak strain of E. coli O157 confirmed from 26 of 45 E. coli O157:H7-positive samples
  - These were from cattle feces (15 samples), wild pig (7 samples), stream water (2 samples) and soil (2 samples)

Human isolates of non-O157 STEC, by serogroup, FoodNet sites, 2000-2006

(Bar chart showing serogroups and their percentage) N=575 isolates* 42 serogroups 1.2% each

Source: CDC 2008

Best Practices: Animal Intrusion

<table>
<thead>
<tr>
<th>Observed fecal matter</th>
<th>Ignored as natural</th>
<th>Segregate 5 ft area</th>
<th>Reject whole field</th>
</tr>
</thead>
</table>

Significant Animal
- Cattle
- Pig
- Deer
- Goat
- Sheep

Non-Significant Animal
- Coyote
- Fox
- Dog
- Cat
- Horse
- Rabbit
- Raccoon
- Birds
- Chickens
- Reptiles
- Amphibians
- Other

LGMA Standards recognize level of concern and required corrective action
Human hygiene

**Humans are involved**
- training and implementation issues

### GAPs Programs Should Not Be Passive

Develop a system that can:
- Determine what could have happened;
- Implement procedures to determine when the process is out of control;
- Implement control measures to correct the problem;
- Verify;
- Record all actions that have been done

### Key Take-Home Messages

- Illness is the vastly exceptional outcome
- Diverse produce consumption is the right health message for a balanced diet